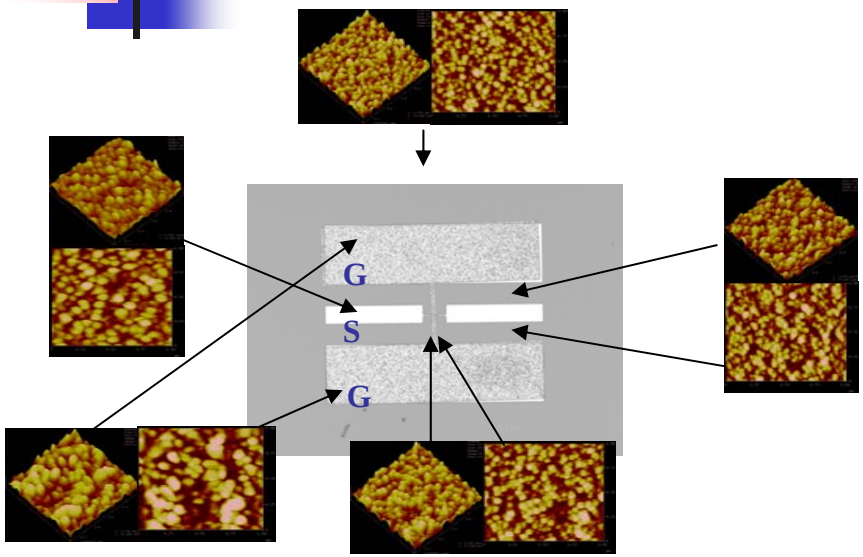
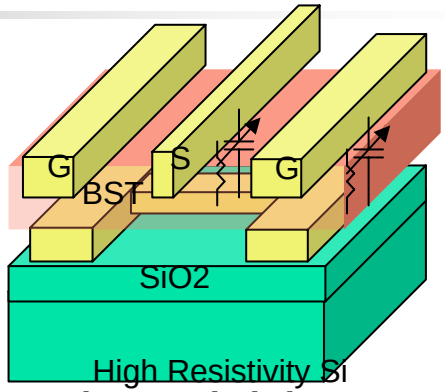
Dr. Guru Subramanyam, Associate Professor, ECE University of Dayton



Nanostructured Barium Strontium Titanate (BSTO) with an Average Grain Size ~63 nm

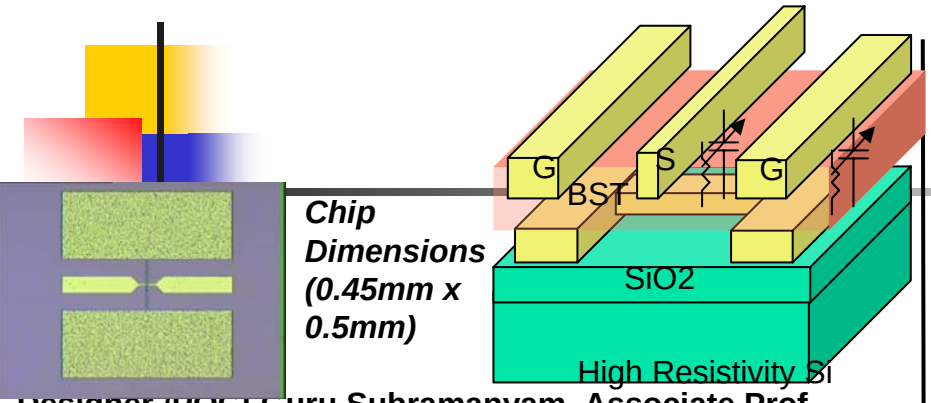
- **Precise control of nanostructure by a AFRL process-controlled PLD system**
- **Large dielectric tunability (>4:1)**
- **Low dielectric loss-tangent (~0.01-0.05) at 20 GHz**



Novel varactor shunt switch (patent pending)

- **Novel Shunt switch, using the nonlinear dielectric tunability of Barium Strontium Titanate thin-films**
- **Normally OFF switch, Simple, low-loss high isolation RF shunt switch, low cost packaging, Si MMIC integration, high speed switching (~40ns) and low power consumption.**
- **Applications: RF switches, Tunable filters, phase shifters, wireless sensors, and passive RFID transponders.**

Novel Ferroelectric Varactor Shunt Switch
For Microwave and Millimeterwave Applications



Chip Dimensions (0.45mm x 0.5mm)

Designer /POC: Guru Subramanyam, Associate Prof.
Dept. of ECE, University of Dayton

- **Performance Goals /Specs:**

For the switch:

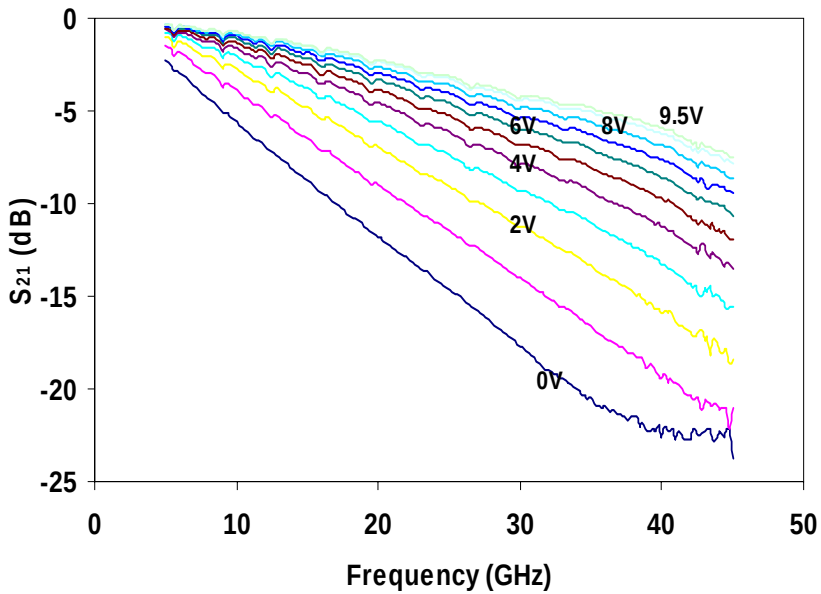
On state insertion loss < 1.0dB @ 25 GHz
Isolation >20 dB @25 GHz

- **Need / Potential Application:** Normally OFF switch, Simple, low-loss high isolation RF shunt switch, low cost packaging, Si MMIC integration, high speed switching (~40ns) and low power consumption**.**

- **Chip Uniqueness /Novelty:** Novel Shunt switch, using the nonlinear dielectric tunability of Barium Strontium Titanate thin-films (device patent pending, UD)

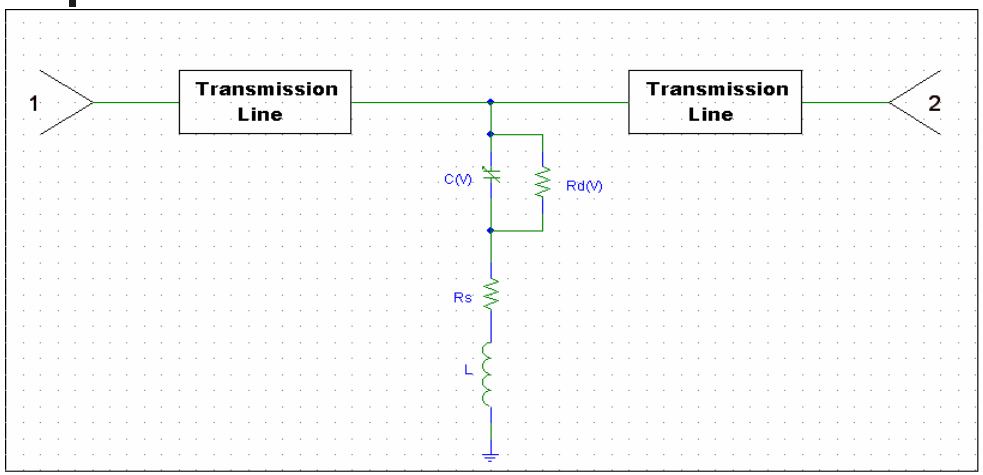
- **Customer /Planned Use:** RF switches, Tunable filters, phase shifters, Signal to Noise enhancers(SNE), leaky wave reconfigurable antennas, wireless sensors, and passive RFID transponders.

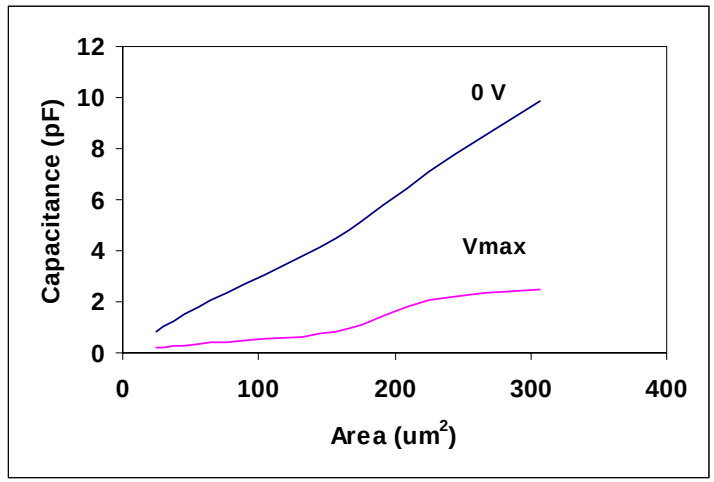
- **Status:**



Device operation experimentally verified.
Device switching speed ~40 ns

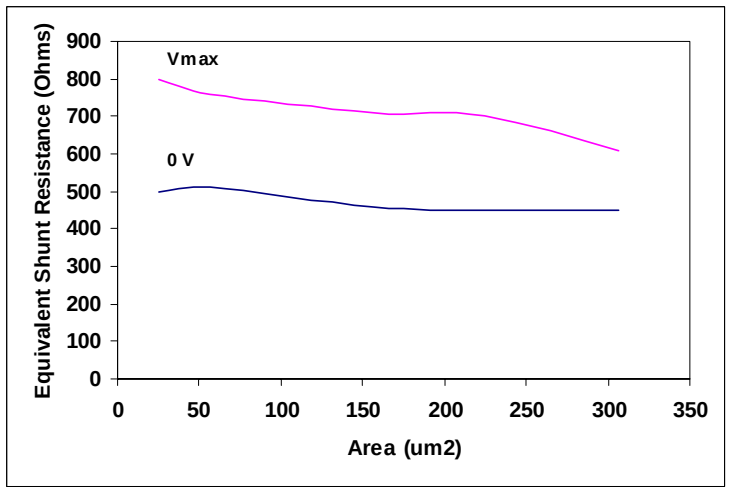
Experimental Device Parameters @ 20 GHz





$$C(V) = \frac{\varepsilon_0 \varepsilon_r(V) A}{t_d}$$

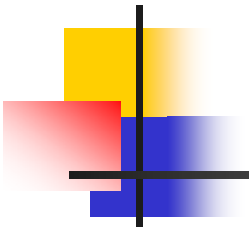
$$R_d(V) = \frac{1}{\omega C(V) \tan\delta}$$



Comparison of Solid state Diodes, RF MEMS and capacitive shunt switches for Microwave applications

Device characteristics and performance parameter	Solid state Diodes	RF MEMS Shunt switches (Normally ON)	Ferroelectric varactor shunt switch (Normally OFF)
Actuation voltage	Low (3-8V)	High(40-50V)	Low (~10V)
Switching speed	High(5-100ns)	Low (~10us)	High(<50ns)
Isolation	<20dB @20 GHz	>30dB @20 GHz	~20 dB @30 GHz
Insertion loss	>1 dB @20 GHz	<1 dB @30 GHz	~3 dB @30 GHz
Switching lifetime	High	Medium	High
Packaging cost	Low	Very high	Low
Power handling	Poor (0.5-5W)	Poor(<4.5W)	Poor (<5 W)
Power consumption	High (1-20mW)	Low	Very Low
Breakdown voltage	Low	Moderate	Low (<20 V)
Linearity	Low	High	High (expected)
IP3	Low(~+28dBm)	High(~+55dBm)	High (expected)
Integration capability	Very good	Good	Very good

Application	Frequency Range	Implementation	Attributes
Switching Device	1-100 GHz	Shunt switch (CPW), Si MMIC compatible	*Lower insertion loss for smaller devices
T/R switch	1-100 GHz	Shunt switch (CPW)	*20-25 dB isolation
Phase Shifter	1-100 GHz	Periodic Loading	*Analog, continuous *up to 75 deg/dB@ 5 GHz
Tunable filters	Microwave/milli meterwave	Periodic Loading	Low voltage tunable, CPW
Signal to Noise Enhancer	Microwave/Milli meterwave	Shunt Switch (CPW)	*High power signals allowed to pass thru
Tunable Impedance Matching Networks	Microwave/Milli meterwave	Periodic Loading + Stub	Voltage controlled Switches
Capacitive Sensors	Low Microwave	Shunt switch (CPW)	*Resonance frequency shift
Leakywave Antennas	Microwave/Milli meterwave	Shunt Switch array	Electronically Steerable



The views, opinions, and/or findings contained in this article are those of the author and should not be interpreted as representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency or the Department of Defense